Substitute Specification (clean version)

**Technical Field**

The present invention relates to a liquid electrophotographic printer and, more particularly, to an electrostatic transfer type liquid electrophotographic printer adopting a photoreceptor web as a photoreceptor medium.

**Background of the Invention**

Electrophotographic printers such as laser printers output a desired image by forming a latent electrostatic image on a photoreceptor medium such as a photoreceptor drum or electroreceptor web, and developing the latent electrostatic image with a predetermined color toner. Electrophotographic printers are classified into a dry type or liquid type according to the toner used. For the liquid type printer, which uses an ink containing liquid carrier and solid toner in a predetermined ratio, it is relatively easy to implement a color image with excellent print quality, compared with the dry type printer which uses solid toner. Electrophotographic printers are also generally classified into an adhesive transfer type and electrostatic transfer type according to the toner image transfer manner. To the adhesive transfer type, after drying a toner image, a transfer roller hot presses the dried toner image such that the image is transferred to a printer paper. The electrostatic transfer type printer transfers a toner image to a print paper by electrostatic forces.

Figure 1 shows an example of a conventional electrostatic transfer type liquid electrophotographic printer, which adopts photoreceptor drums 10a, 10b, 10c and 10d as photoreceptor media. As shown in Figure 1, this printer has a plurality of image forming units 1a, 1b, 1c and 1d for developing and transferring a predetermined color image to a print paper P. For a color printer, the four image forming units 1a, 1b, 1c and 1d for a color image development and transfer are arranged in a line in the direction of transferring the print paper P such that toner images are sequentially developed into four colors, yellow (Y), magenta (M), cyan (C), and black (K) to form a multi-color image. Reference numeral 2 denotes a feed belt 2 for feeding the print paper P.

The image forming units 1a, 1b, 1c and 1d include photoreceptor drums 10a, 10b, 10c and 10d on the surface of which a latent electrostatic image is to be formed, main chargers 20a, 20b, 20c and 20d adjacent to the corresponding photoreceptor drums 10a, 10b, 10c and 10d to charge the surfaces of the photoreceptor drums 10a, 10b, 10c, and 10d to a predetermined potential, and laser scanning units (LSUs) 30a, 30b, 30c and 30d which scan light beams onto the surfaces of the respective photoreceptor drums 10a, 10b, 10c and 10d to form a latent electrostatic image thereon. Development units 50a, 50b, 50c and 50d that develop the latent electrostatic images into toner images with a predetermined color ink are installed below the respective photoreceptor drums 10a, 10b, 10c and 10d. Transfer chargers 70a, 70b, 70c and 70d which transfer the developed toner images formed on the respective photoreceptor drums 10a, 10b, 10c and 10d to a print paper P by electric force are spaced a predetermined distance apart from the surface of the corresponding facing photoreceptor drums 10a, 10b, 10c and 10d.

The structure of the development units 50a, 50b, 50c and 50d will be described with reference to the development unit 50a for yellow (Y) toner image (referred to as Y-development unit 50a). Referring to Figure 2, a developer roller 51, a squeeze roller 52 and a setting roller 53 are installed in the Y-development unit 50a. An ink supply unit 57 for supplying an ink to the developer roller 51 is installed adjacent to the developer roller 51. Scrapers 54, 55 and 56 are attached to the lower portion of the developer roller 51, the squeeze roller 52 and the setting roller 53, respectively, to scrape off the ink adhering to the surface of the corresponding rollers.

Development of a Y-toner image by the Y-development unit 50a having the configuration above will be described in greater detail. First, as the surface of the photoreceptor drum 10a charged to a predetermined potential by the main charger 20a and is irradiated by a light beam from the LSU 30a, a latent electrostatic image corresponding to the yellow color is formed. The developer roller 51 of the Y-development unit 50a rotates counterclockwise while being separated by a predetermined distance from the photoreceptor drum 10a. As ink is supplied to the rotating developer roller 51 from the ink supply unit 57, the ink is carried to the gap between the photoreceptor drum 10a and the developer roller 51 by the rotation of the

developer roller 51. The toner particles of the ink adhere to the latent electrostatic image formed on the photoreceptor drum 10a, so that a toner image is formed. At this time, the surface of the developer roller 51 is charged to a predetermined development potential such that the toner selectively adheres to only the latent electrostatic image, not to a non-image region.

The squeeze roller 52 removes excess liquid carrier from the photoreceptor drum 10a while being separated by a predetermined distance from the photoreceptor drum 10a and rotating clockwise. The setting roller 53 rotates counterclockwise while being separated by a predetermined distance from the photoreceptor drum 10a, and creates an electric field between the photoreceptor drum 10a and the setting roller 53 with application of a predetermined voltage. The binding force between toner particles becomes strengthened by the electric field produced between the setting roller 53 and the photoreceptor drum 10a. Adhesiveness of the toner image to the photoreceptor drum 10a also increases. As a result, although an excessive amount of liquid carrier remains on the surface of the photoreceptor drum 10a for a subsequent electrostatic transfer, the shape and location of the toner image can be kept intact.

Once the toner image is set by the setting roller 53, the toner image is transferred to a print paper P by the electric field produced by the transfer charger 70a to which a potential is applied such that the transfer charger 70a is charged to the opposite polarity to the toner.

After a Y-toner image is transferred to the print paper P by the Y-image forming unit 1a, a magenta (M)-toner image is developed and transferred to the print paper P by the M-image forming unit 1b. As previously described, four toner images in Y, M, C and K are sequentially transferred to a predetermined area on the print paper P fed by the feed belt 2 in accordance with the print paper feed rate, so that a color image is printed on the print paper P. Because a large amount of liquid carrier remains on the resulting color image, a drying process is performed by a drying unit (not shown).

The conventional electrostatic transfer type liquid electrophotographic printer having the configuration described above has the following drawbacks. First, since the conventional printer uses four photoreceptor drums as photoreceptor media, each for a particular color toner image, the multi-color toner images on the four photoreceptor

drums must be sequentially transferred to a moving print paper with a predetermined time gap. The respective color toner images are separately transferred, and thus it is difficult to accurately transfer each of the color toner images in a particular area on the print paper in accordance with the print paper feed rate. In other words, an accurate registration control on the development and transfer processes performed by each image-forming unit is difficult.

Second, four toner image transfer processes are carried out on a print paper fed by a feed belt, so that the print paper contacts the liquid carrier adhering to the surface of the photoreceptor drums four times. As a result, unnecessary consumption of the liquid carrier increases and the wetness of the print paper also increases.

Third, because the squeeze roller removes liquid carrier in a non-contact manner with respect to the photoreceptor drums, the amount of the liquid carrier remaining on the surface of the photoreceptor drums is nonuniform for all the image forming units. As a result, toner image transfer efficiency differs from color to color. It is therefore desirable to provide an electrostatic transfer type liquid electrophotographic printer for applying multiple colors to print paper that overcomes the drawbacks discussed above.

## Summary of the Invention

In one aspect of this invention, an electrostatic transfer type liquid electrophotographic printer is provided, which generally includes a photoreceptor web, at least one exposing unit, at least one development unit, and an electrostatic transfer unit. More particularly, the electrophotographic printer of the present invention preferably includes a continuous photoreceptor web having a charged surface and an opposing back surface, wherein the web rotates around a printing path. The printer further preferably includes at least one laser scanning unit for scanning a light beam onto the charged surface of the photoreceptor web to form a latent electrostatic image and at least one development unit for developing the latent electrostatic image on the photoreceptor web into a toner image with an ink containing a liquid carrier and charged toner particles, wherein each development unit preferably includes a developer roller, a toner removal roller, a squeeze roller, a developer backup roller, a toner removal backup roller, and a squeeze backup roller. The photoreceptor web is arranged

to provide at least 1 degree of contact wrap around at least one of the backup rollers that correspond to the developer roller, the toner removal roller, and the squeeze roller. The electrostatic transfer unit of the electrophotographic printer preferably provides for transferring the toner images formed in each development unit from the photoreceptor web to a print medium by electrostatic force.

## Brief Description of the Drawings

The present invention will be further explained with reference to the appended Figures, wherein like structure is referred to by like numerals throughout the several views, and wherein:

Figure 1 is a schematic view of one representative system of the liquid electrophotographic apparatus of the prior art;

Figure 2 is a schematic view of one development unit of the apparatus of Figure 1;

Figure 3 is a schematic view of a liquid electrophotographic apparatus of the present invention, including a backup roller corresponding to each roller in each developer unit, a partial mechanical wrap of the photoreceptor web around each backup roller, and the effect that this mechanical wrap has on the design of the machine, namely, the "arc" of the photoreceptor frame;

Figure 4 is a schematic view of one development unit of the system of Figure 3, including backup rollers and a mechanical wrap of a photoreceptor web relative to those rollers;

Figure 5 is a schematic view of one embodiment of the liquid electrophotographic toner transfer process of the present invention; and

Figure 6 is a schematic view of a back up roller positioned relative to a roller of a development unit of the liquid electrophotographic apparatus.

## Detailed Description of the Preferred Embodiments

Referring now to the Figures, wherein the components are labeled with like numerals throughout the several Figures, and initially to Figure 3, one preferred configuration of an electrostatic transfer type liquid electrophotographic printer 100 is

illustrated, in accordance with the present invention. This printer 100 generally uses a photoreceptor web 110 circulating around a continuous path as a photoreceptor medium. This configuration includes aspects of the transfer type liquid electrophotographic printer of the type described in United States Patent Application Publication No. 2002/0110390, the entire contents of which are incorporated herein by reference.

As shown in Figure 3, the electrostatic transfer type liquid electrophotographic printer 100 utilizes a photoreceptor web or belt 110 as a photoreceptor medium. The photoreceptor web 110 is preferably supported by three rollers 111,112 and 113, including a driving roller and a steering roller. In the preferable embodiment, roller 111 is a driving roller and roller 112 is a steering roller; however, it is possible that roller 112 is a driving roller and roller 111 is a steering roller, or it is also possible that other driving and/or steering rollers are included in the printer configuration. Roller 113 may be referred to as a transfer backup roller, as this is the roller against which transfer of an image from the photoreceptor web 110 to a print paper 102 occurs. This roller 113 is preferably biased in order to effect electrostatic transfer of an image to print paper 102 or other medium. The photoreceptor web 110 circulates or moves around a continuous path or loop that is defined by the outer surfaces of the rollers 111, 112, and 113. The arrows 114, 115, and 116 show the direction of rotation of the rollers 111, 112, and 113, respectively, which roller rotation effects the movement of the photoreceptor web 110 in the direction indicated by arrows 260 and 262. Alternatively, the rollers 111, 112, and 113 could all rotate in the opposite direction to cause the photoreceptor web 110 to move in the opposite direction; however, this would require repositioning of at least some of the other system components relative to the location of other components in the system. Additional or different rollers may be provided within the system, as desired, which would thereby change the path of the photoreceptor web 110 needed to encircle these rollers in a similar manner to that shown in Figure 3.

A main charger 120 is shown adjacent to the photoreceptor web 110 to uniformly charge the photoreceptor web 110 to a predetermined potential. As shown, main charger 120 is located between the rollers 113 and 111 so that the photoreceptor

web 110 can be charged to a particular potential before being exposed to the components of the system that provide ink to the photoreceptor web 110, as described below. The main charger 120 is preferably sized and positioned so that it can sufficiently charge the photoreceptor web 110 to allow an electrostatic image to be formed thereon by at least one development unit. It is possible that additional chargers are provided (not shown), such as before the photoreceptor web 110 reaches some or all of laser scanning units 140a, 140b, 140c and/or 140d. It is also possible that squeeze rollers 153a, 153b, 153c and/or 153d of development units 150a, 150b, 150c and/or 150d described below are sufficiently biased to charge the photoreceptor web 110 periodically through the process. In any case, it is preferable that the photoreceptor web 110 is recharged in the development units 150a, 150b, 150c, and 150d after each color is provided to the photoreceptor web 110.

Laser scanning units (LSUs) 140a, 140b, 140c and 140d and development units 150a, 150b, 150c and 150d are preferably provided below the photoreceptor web 110 (i.e., to contact the front surface 193 of the photoreceptor web 110) and between the rollers 111 and 112. The LSUs 140a, 140b, 140, and 140d are used for scanning light beams onto the charged photoreceptor web 110 to form a latent electrostatic image, and development units 150a, 150b, 150c and 150d are used for developing the latent electrostatic image as a toner image, each with a predetermined color ink. To form a multi-color image, for example, an electrophotographic printer would preferably be provided with four ink reservoirs 159a, 159b, 159c, and 159d, each containing one of the ink colors of yellow (Y), magenta (M), cyan (C) and black (B), four LSUs 140a, 140b, 140c and 140d, and four development units 150a, 150b, 150c and 150d. With these components, toner images of four different colors can be sequentially formed, overlapping or overlying each other, and developed into a multi-color image. As shown, the four development units 150a, 150b, 150c and 150d are arranged sequentially below the photoreceptor web 110 with their respective rollers in a rotation movement or circulation direction of the photoreceptor web 110. The structure and operation of the development units 150a, 150b, 150c and 150d will be described later in greater detail.

In a lower portion of the respective development units 150a, 150b, 150c and 150d, ink reservoirs 159a, 159b, 159c and 159d, which contain Y, M, C and K inks,

respectively, are provided. Toner charged to a predetermined polarity is dispersed in a liquid carrier in the inks contained in the ink reservoirs 159a, 159b, 159c and 159d. The concentration of ink is preferably in the range of about 2.0-3.0%, and more preferably about 2.5%, where the term "concentration" refers to the weight percentage of toner solids with respect to carrier liquid. Although it is understood that the present invention is equally applicable to systems where the toner is charged to either a positive or negative potential, the description below is directed to the toner being charged to a positive potential. When the toner is charged to a negative potential, the opposite charging of other components and processes described below (that refer to charges of a positive potential) will be used. In addition, the four color toner images may be developed in an order that is different from the preferable order of Y, M, C, and then K, as described above, such as in the order of Y, C, M, and then K, for example.

After the image comprising at least one color is formed on the photoreceptor web 110 (i.e., the photoreceptor web 110 has passed by the development units 150a, 150b, 150c, and 150d, at least one of which has provided ink to the photoreceptor web 110), the image may then be transferred to a piece of paper or other final image receptor. In this configuration, a print paper 102 is shown adjacent to the roller 113 for accepting the image from the photoreceptor web 110. In many cases, it may be possible to achieve more than 99% transfer efficiency at an ink solids concentration of 20-40%. In other words, the percentage of the toner images transferred from the photoreceptor web 110 to a print paper 102, or the "transfer efficiency", may be higher than 99% at a concentration of 20-40%. If the toner concentration is relatively high (e.g., exceeds 40% by weight), the electrostatic transfer process may be more difficult to perform due to reduced fluidity of the toner, thereby lowering transfer efficiency. If the toner concentration is relatively low (e.g., below 20% by weight) and the liquid carrier content is too high, toner image leaking may occur on the print paper 102 due to highly increased fluidity of the toner. In addition, when the toner concentration is relatively low, it is less likely that the toner images can be kept intact before being transferred to a print paper 102. If the toner concentration is relatively high (e.g., above 40% by weight), the electrostatic transfer process may become more difficult or impossible; however, it may be possible to successfully transfer the image using

adhesive transfer with certain temperatures and pressures, as desired.

The toner images developed on the surface of the photoreceptor web 110, whose toner concentration has preferably been adjusted to be suitable for electrostatic transfer, can be transferred to the print paper 102 by an electrostatic transfer unit. Such an electrostatic transfer unit forms an electric field between the photoreceptor web 110 and the electrostatic transfer unit so that the toner images formed on the photoreceptor web 110 are transferred to the print paper 102 by the electric force. As shown in Figure 3, an electrostatic transfer roller 170 may be used as the electrostatic transfer unit. The electrostatic transfer roller 170 rotates in a rotation direction 171 while preferably being in contact with the photoreceptor web 110 when no paper is present, although a gap provided between the electrostatic transfer roller 170 and photoreceptor web 110 is possible. When the print paper 102 is fed between the electrostatic transfer roller 170 and the photoreceptor web 110, the electrostatic transfer roller 170 will then be in contact with the print paper 102. To create an electric field, a predetermined voltage of 900V-2 kV, for example, is preferably applied to the electrostatic transfer roller 170. It is noted, however, that the polarity of the transfer voltage is determined based on the polarity of the ink particles. The surface of the electrostatic transfer roller 170 is preferably formed of a resistive material having a high resistance of $10^8$-$10^9$ ohms, for example. One possible material from which the electrostatic transfer roller 170 may be made is conductive urethane rubber, or may include a roller made of multiple materials, such as a roller comprising an inner core made of a material such as steel and having an outer coating of urethane rubber, for example. The reason that a voltage having the opposite polarity to the toner is applied to the electrostatic transfer roller 170 is to attract the toner such that a toner image can be transferred to the print paper 102.

A fusing unit 180 for fusing the toner images transferred to the print paper 102 may be provided at the paper eject side of the electrostatic transfer roller 170. The fusing unit 180 may include two or more fusing rollers 181 and 182 rotating in opposite directions and in contact with each other until a print paper 102 or other transfer medium is introduced between the fusing rollers 181 and 182 for fusing. The fusing rollers 181 and 182 fix the toner images on the print paper 102, which passes between the fusing rollers 181 and 182, by hot pressing. The printer 100 may further include an

eraser unit 190 for removing the remaining latent electrostatic images from the surface of the photoreceptor web 110.

Hereinafter, the development units 150a, 150b, 150c and 150d will be described in greater detail. In the embodiment illustrated in Figure 3, the three development units 150a, 150b and 150c, exclusive of the K-development unit 150d (a development unit for black (K)), preferably have generally the same structure. A concentration control unit 160 can optionally be installed in the K-development unit 150d, thereby making the structure of this development unit different from the structure of the others. If such a concentration control unit is not used, the structure of the K-development unit 150d may be the same as the other development units 150a, 150b, and 150c, with a single roller replacing the two rollers 152d shown in K-development unit 150d. The structure of the three development units 150a, 150b and 150c, which are preferably the same, will be described first with reference to the Y-development unit 150a (a development unit for yellow (Y)) of Figure 4.

Referring additionally to Figure 4, which shows components of the development unit 150a that are not shown in Figure 3 (for clarity purposes), three rollers including a developer roller 151a, a toner removal roller 152a, and a squeeze roller 153a are installed in an upper portion of the Y-development unit 150a. This embodiment of the electrostatic transfer type liquid electrophotographic printer 100 according to the present invention employs a development system that preferably uses these three rollers 151a, 152a and 153a. It is contemplated, however, that a different number of rollers and/or rollers having different functions could be used. In this embodiment, the developer roller 151a is used to make the toner particles of the ink adhere to the latent electrostatic images formed in an image region of the photoreceptor web 110 to form toner images. The toner removal roller 152a is used to remove the toner adhering to the non-image region of the photoreceptor web 110. To this end, a predetermined voltage is preferably applied to the toner removal roller 152a, as will be described in further detail below. The squeeze roller 153a is used to press a portion of the photoreceptor web 110 in which toner images are formed to squeeze excess liquid carrier from the portion, thereby aggregating the toner particles forming the toner images. A relatively high voltage is preferably applied to the squeeze roller 153a so that the photoreceptor

web 110 can be charged by the squeeze roller 153a to a predetermined potential for another color toner image development. To this end, at least the surface of the squeeze roller 153a is preferably formed of a resistive material with a high resistance of $10^5$-$10^7$ ohms, and more preferably, $10^6$ ohms (e.g., urethane rubber).

An ink supply nozzle 158a is preferably installed adjacent to the developer roller 151a. This ink supply nozzle 158a supplies the ink contained in the Y-ink reservoir 159a (see Figure 3) in the gap between the photoreceptor web 110 and the developer roller 151a. A cleaning roller 154a rotating in contact with the developer roller 151a may be installed below the developer roller 151a for removing the ink adhering to the surface of the developer roller 151a. A blade 155a is preferably disposed underneath the toner removal roller 152a, while one of its ends is in contact with the surface of the toner removal roller 152a. A blade 156a is preferably disposed underneath the squeeze roller 153a, while one of its ends is in contact with the surface of the squeeze roller 153a. The two blades 155a and 156a act to remove the ink or liquid carrier adhering to the surface of the toner removal roller 152a and the squeeze roller 153a, respectively. As the cleaning means, the cleaning roller 154a and the blades 155a and 156a are interchangeable. In other words, either one or both of a cleaning roller and a blade may be installed for each of the rollers 151a, 152a and 153a.

Continuing to refer to Figures 3 and 4, each of the developer rollers 151a, 152a, 153a is preferably provided with a corresponding backup roller 251a, 252a, 253a, respectively. The backup rollers 251a, 252a, 253a are positioned to be adjacent to the back side 194 of the photoreceptor web 110, and are positioned to press snugly against the photoreceptor web 110, creating a mechanical wrap that is preferably at least about 1 degree around each backup roller 251a, 252a, 253a. This wrap of the photoreceptor web 110 can be selected and controlled through the positioning of the various rollers in the development units 150a, 150b, 150c, and 150d to create a relatively continuous "arc" or curve of the photoreceptor web 110 from the general area of roller 111 to the general area of roller 112. The arc or curve preferably extends from the first development roller that the photoreceptor web 110 passes (e.g., roller 151a) to the last development roller that the photoreceptor web 110 passes (e.g., roller 153d) of the multiple development units 150a, 150b, 150c, and 150d. In addition, while a

mechanical wrap of at least about 1 degree on all of the rollers is preferable, the wrap angle may be different with respect to some of the rollers, where the wrap for some of the rollers is above 1 degree and the wrap on other rollers is less than 1 degree, for example. However, the degree of wrap on any of the rollers should be greater than 0 degrees, in accordance with the present invention.

The application of backup rollers in this system that press firmly enough against the backside 194 of the photoreceptor web 110 to form such a mechanical wrap around at least some of the backup rollers is advantageous in that the critical gaps between the rollers and photoreceptor web 110 can be more easily established and maintained. The developer rollers 151a, 152a, 153a and backup rollers 251a, 252a, 253a have diameters that are chosen with a preferable nip width $N_1$, $N_2$, $N_3$ in mind. The pairs (151a and 251a; 152a and 252a) of rollers are each carefully spaced to provide precise gap distances $G_1$ and $G_2$ between the roller 151a and the web 110 and between the roller 152a and the photoreceptor web 110, respectively. In particular, the gap $G_1$ between the roller 151a and the photoreceptor web 110 is preferably maintained at a certain distance to facilitate electrostatic transfer of charged toner pigment particles to the photoreceptor web 110. If this gap $G_1$ is too large, a sufficient portion of the toner might not transfer to the photoreceptor web 110, thereby causing poor printing quality. If the gap $G_1$ is too small, the transfer of toner might transfer to the photoreceptor web 110 by a different process than electrostatic transfer, which might also cause poor printing quality. Further, the gap $G_2$ between the roller 152a and the photoreceptor web 110 is preferably maintained at a certain distance so that the thickness of the toner or "toner patch" can be properly controlled or metered. Thus, if the gap $G_2$ is too large, the toner will be thicker than desired and if the gap $G_2$ is too small, the toner will be thinner than desired, wherein both thickness variations can detrimentally effect the quality of the toner image that remains on the photoreceptor web 110. In any case, the printer 100 may further include additional cleaning means to remove any residual ink from the photoreceptor web 110 after transfer of the toner images.

Additionally, the backup roller 253a against which the squeeze roller 153a can press may be selected to be a heavier roller having reduced flexibility, such that an increased force may be uniformly distributed along the nip $N_3$. When the backup roller

253a is a heavier roller, the roller may impart a force that is preferably between about 1 kg and 15 kg, and more preferably between about 5 kg and 10 kg. However, in the case of electrostatic transfer processes, the amount of force required in the nip $N_3$ to squeeze excess carrier from the image would typically be minimal. Preferably, the pressure across the width of this nip $N_3$ is relatively consistent across the entire width of the rollers, and it is further preferable that the amount of pressure applied is adjustable, as desired.

With respect to the rollers of the development unit 150d, the provision of backup rollers is similar to that described above relative to the development units 150a, 150b, and 150c, except that when a concentration control unit 160 is used, each of the two rollers 152d of the concentration control unit is preferably provided with its own corresponding backup roller 252d. In this way, pressure may be placed on the rollers of the development unit 150d in the same manner as described for the other development units. Thus, for each roller in each developer unit (151a, 152a, 153a, 151b, 152b, 153b, 151c, 152c, 153c, 151d, 152d, 153d) there is preferably a corresponding backup roller (251a, 252a, 253a, 251b, 252b, 253b, 251c, 252c, 253c, 251d, 252d, 253d, respectively) pressed against the backside 194 of the photoreceptor web110 with a mechanical wrap of preferably at least 1 degree around each backup roller. In the embodiment shown, certain pairs of rollers have a carefully selected gap between them (151a and 251a; 152a and 252a; 151b and 251b; 152b and 252b; 151c and 251c; 152c and 252c; 151d and 251d; 152d and 252d), as described above. Some of the pairs of rollers (e.g., 153a and 253a; 153b and 253b; 153c and 253c; 153d and 253d) may not have a gap between them. Rather, the squeeze rollers (153a, 153b, 153c, and/or 153d) may actually contact the front surface 193 of the photoreceptor web 110 at the same time that the corresponding backup rollers (253a, 253b, 253c, and/or 253d) contact the back surface 194 of the photoreceptor web 110.

Referring also to Figure 6, a representative roller 208 of a development unit is shown (which has a similar configuration to two paired rollers in one of the development units of a printer of the present invention), along with its corresponding backup roller 202, to illustrate a simplified view of a gap 204 between two rollers. Roller 208 is rotatable in a direction 214 and backup roller 202 is rotatable in an

opposite direction 212, as shown. A backup roller, such as roller 202, is preferably provided at each nip area, and is preferably positioned to allow at least about 1 degree of mechanical wrap of the photoreceptor web 206 about its outer surface. This roller 202 can advantageously maintain the gap 204 and the contact nip between the development unit roller 208 and a photoreceptor web 206 at a predetermined, desirable distance. Thus, it is preferable that the rollers of a printer of the present invention are adjustable to maintain the desired gaps, nip sizes, and/or compression forces between rollers and the photoreceptor web, where such adjustability may either be automatic (as may be controlled by electronic measurements and feedback loops, for example) or be manual (as may be adjusted by manual movement of the rollers when it is determined that the print quality can be improved with a change in the size of the gap, for example). In any given pair of rollers (e.g., a developer roller and its corresponding back-up roller), either one or both of the rollers may be adjustable for maintaining the gap size, where moving the back-up roller will typically also change the wrap of the photoreceptor web around that back-up roller, which may also be desirable in some cases. If such a change in the wrap of the photoreceptor web around a particular back-up roller is not desirable, the other roller (e.g., the developer roller) may instead be moved to adjust the size of the gap.

Development of a latent electrostatic image into a toner image by the Y-development unit 150a having the configuration described previously will be further described with reference to Figure 5, which is a magnified illustration of a portion of the development unit 150a of Figure 4. As described above relative to Figure 3, before the photoreceptor web 110 reaches the development units 150a, 150b, 150c, and 150d, the main charger 120 charges the photoreceptor web 110 to a potential (referred to as a charge potential), for example, of 500-900 volts, and preferably, 550-750 volts, and having the same polarity as the toner. The charged surface of the photoreceptor web 110 is then irradiated by a light beam from the Y-LSU (LSU for yellow) 140a so that a latent electrostatic image corresponding to yellow color is formed. The Y-LSU 140a selectively discharges the surface of the photoreceptor web 110 to form a latent electrostatic image, so that a potential of the image region $B_1$, in which the latent electrostatic image is formed, drops to about 100 volts or less (referred to as exposure

potential), while a potential of the non-image region $A_1$ is maintained at the initial charge potential charged by the main charger 120.

The latent electrostatic image is developed into a Y-toner image by the Y-development unit 150a. In particular, as the photoreceptor web 110 passes over the developer roller 151a, Y-toner adheres to the image region $B_1$, in which an electrostatic latent image is formed, to form a Y-toner image. As a predetermined voltage is applied to the developer roller 151a, the surface of the developer roller 151a is charged to a development potential $V_D$ of about 350 volts, for example. The development potential $V_D$ of the development roller 151a is determined to be lower than the charge potential (e.g., 550 V) of the non-image region $A_1$, and to be higher than the exposure potential (e.g., 100 V) of the image region $B_1$. It is preferable that differences between the development potential $V_D$ and each of the charge potential and the exposure potential are 100 volts or more, and more preferably, 200 volts or more. As the potential differences become greater, the affinity of toner particles to the photoreceptor web 110 and the developer roller 151a becomes more apparent. The developer roller 151a rotates in the circulation direction of the photoreceptor web 110 while being separated by a development gap $G_D$ (e.g., 150-200 μm) from the photoreceptor web 110. In one example, as an ink contained in the Y-ink reservoir 159a containing Y-toner of about 2.5% solids by weight is supplied by the ink supply nozzle 158a, a nip $N_D$ as a liquid carrier film having about 6-mm width is formed between the photoreceptor web 110 and the developer roller 151a. It is understood that as the weight percent of toner and other variables are changed, the size of any nips and gaps may differ.

In this example, the toner particles of the ink are preferably charged to positive potential and move in the nip $N_D$ as follows. The exposure potential (e.g., 100 volts) in the image region $B_1$ of the photoreceptor web 110 is lower than the development potential (e.g., 350 volts) of the development roller 151a, so that the toner particles move toward the image region $B_1$ and adhere to the image region $B_1$. The charge potential (e.g., 550 volts) in the non-image region $A_1$ is greater than the development potential $V_D$ (e.g., 350 volts) of the developer roller 151a, so that the toner particles move towards the developer roller 151a and adhere to the developer roller 151a. In other words, the toner particles selectively adhere to only the image region $B_1$ charged

to a relatively low potential, so that toner images are formed therein. Excess ink and toner particles stuck to the surface of the developer roller 151a can be removed by a cleaning device such as the cleaning roller 154a rotating in contact with the developer roller 151a, as previously described.

On the image region $B_2$ corresponding to the image region $B_1$ passed through the developer roller 151a, an ink layer of a high-concentration toner image is formed and covered with a liquid carrier layer. On the non-image region $A_2$, only a liquid carrier layer is formed. In the image region $B_2$ passed through the developer roller 151a, the potential increases to about 160 volts, for example. The potential in the non-image region $A_2$ would then preferably drop to about 380 volts, for example. It is desirable that no toner remains in the liquid carrier layers passed through the developer roller 151a. However, in some situations, some toner (e.g., about 0.5% by weight toner) remains in the liquid carrier layers. The remaining toner particles can be transferred to the M-development unit 150b along the photoreceptor web 110, and mixed with toner of another color. As a result, the M-development unit 150b, C-development unit 150c, and K-development unit 150d, which are sequentially arranged, and the inks for each color, can be contaminated by the transfer of toner particles. Thus, there is a need to remove the toner particles remaining in the liquid carrier layers to minimize such contamination.

The toner particles remaining in the liquid carrier layers are preferably removed by the toner removal roller 152a disposed adjacent to the developer roller 151a. As the photoreceptor web 110 passes the toner removal roller 152a, toner particles remaining in the liquid carrier layer in the non-image region $A_2$ are removed, thereby resulting in a toner-free liquid carrier layer in the non-image region $A_2$. In particular, the surface of the toner removal roller 152a is preferably charged to a toner removal potential $V_R$ of about 250 volts, for one example, with application of a predetermined voltage. The toner removal potential $V_R$ of the toner removal roller 152a is determined to be greater than the exposure potential (e.g., 160 volts) in the image region $B_2$ and lower than the potential (e.g., 380 volts) in the non-image region $A_2$. As a potential difference in each region becomes greater, it is much easier to remove the toner particles from the liquid carrier layer. The toner removal roller 152a is installed with a preferable gap $G_R$ of

about 150-200 μm, for example, from the photoreceptor web 110. A nip $N_R$ having a width of 3mm to 5mm, for example, may be formed between the toner removal roller 152a and the photoreceptor web 110. The width of the nip $N_R$ may be varied depending on the diameter of the toner removal roller 152a and the size of the gap $G_R$. It is understood that as the weight percent of toner is varied, the size of any nips may differ. Although the toner removal roller 152a can rotate in either direction, it is preferable that the toner removal roller 152a rotates in an opposite direction from the circulation direction of the photoreceptor web 110 for easier formation of the nip $N_R$.

In one example, in the nip $N_R$ formed between the photoreceptor web 110 and the toner removal roller 152a, the toner particles move as follows. In the non-image region $A_2$ of the photoreceptor web 110, the potential (e.g., 380 volts) is higher than the toner removal potential $V_R$ (e.g., 250 volts) of the toner removal roller 152a, so that toner particles dispersed in the liquid carrier layer can move towards the toner removal roller 152a. The potential (e.g., 160 volts) in the image region $B_2$ is lower than the toner removal potential $V_R$ (e.g., 250 volts) of the toner removal roller 152a, so that the toner particles move towards the image region $B_2$ and adhere to a previously formed toner image. As the toner removal roller 152a rotates, a removal device, such as the blade 155a of Figure 4, removes the toner particles and liquid carrier adhering to the surface of the toner removal roller 152a.

As described previously, the toner particles existing in the liquid carrier layer on the non-image region $A_2$ can be almost completely removed by the toner removal roller 152a, so that a toner-free liquid carrier remains in the non-image region $A_3$ of the photoreceptor web 110 passed through the toner removal roller 152a. As a result, the problem of toner transfer to the adjacent development unit can be lessened.

Next, as the photoreceptor web 110 advances to the squeeze roller 153a, the squeeze roller 153a presses the toner image region of the photoreceptor web 110, so that excess liquid carrier is squeezed from the toner image. In particular, the squeeze roller 153a preferably rotates in the circulation direction of the photoreceptor web 110 in contact with the photoreceptor web 110 with a compression force, for example, of about 10 kg. As a result, the liquid carrier covering the toner image in the image region $B_3$ of the photoreceptor web 110, and the liquid carrier adhering to the non-image

region $A_3$ are removed so that just an appropriate and desired amount of the liquid carrier remains therein. Once the photoreceptor web 110 passes the squeeze roller 153a, a toner image is formed as an ink layer containing, for example, about 50% by weight toner in the image region $B_3$ of the photoreceptor web 110. Any liquid carrier stuck to the surface of the squeeze roller 153a can be removed by a removal device, such as the blade 156a of Figure 4, and recovered into the Y-ink reservoir 159a. The reason that the concentration of the toner image will typically be increased is to protect the toner image from being washed off by the ink applied to the same to form a toner image in another color.

The squeeze roller 153a also can act to charge the photoreceptor web 110 again to a predetermined potential to develop a toner image in another color, such as in the next sequential development unit. To this end, a relatively high voltage may be applied to the squeeze roller 153a so that the surface of the squeeze roller 153a is charged to a squeeze potential $V_S$ of about 800 volts or more, for example, which is higher than the charge potential. Thus, once the photoreceptor web 110 passes the squeeze roller 153a, the potential in the non-image region $A_3$ of the photoreceptor web 110 and the potential in the image region $B_3$ are equal to or higher than the charge potential. This can allow for development of a toner image of another color.

Because the surface of the squeeze roller 153a is charged to a relatively high potential, a toner image is formed in the image region $B_3$ by the repulsive force exerted between the squeeze roller 153a and the toner particles, and firmly adheres to the image region $B_3$ with increased binding force of the toner particles. As a result, no thinning of the toner image at its edges occurs by the pressing of the squeeze roller 153a. In addition, washing-off of the toner image by an ink applied to form another toner image does not typically occur, so that the shape and location of the toner image can be maintained intact.

After a Y-toner image is formed through the steps described above, in order to then develop a toner image of magenta (M), the surface of the photoreceptor web 110 is preferably irradiated by a light beam from the M-LSU 140b so that a latent electrostatic image corresponding to a M-toner image is formed. This latent electrostatic image can have a potential of about 100 volts, for example, and can be developed into a M-toner

image by the M-development unit 150b in the same manner as for the Y-toner image, as described previously. Then a toner image of cyan (C) can sequentially be developed by the C-development unit 150c. This process is facilitated by the toner particles from Y, M, and C inks being selected to be transparent to the exposing wavelength.

After toner images are developed in three colors including yellow (Y), magenta (M) and cyan (C), a black (K) toner image can be developed by the K-development unit 150d. The concentration of the overlapping toner images previously formed on the photoreceptor web 110 can be adjusted to be suitable for electrostatic transfer by the K-development unit 150d.

The use of various rollers, particularly backup rollers, in the printer of the present invention is advantageous to maintain important gaps between rollers of the development units and the photoreceptor web or belt. Thus the gap development and maintenance as illustrated and explained relative to Figures 4 and 5 (both discussed above) is important to this apparatus. The maintenance of the various gaps between rollers at particular distances will affect print quality and image density. Without such backup rollers, it may be difficult to maintain the desired gaps for each nipped area (typically, two per developer unit) over the length of the photoreceptor web 110 (Figure 3, between rollers 111 and 112). This is because capillary forces of the liquid ink in the controlled gap ($G_1$ and $G_2$ in Figure 4) will act to pull the photoreceptor web 110 toward the developer roller, such as roller 151a of Figure 4, and toward the toner removal roller, such as roller 152a of Figure 4. If the tension of the photoreceptor web 110 is increased to resist the capillary force, belt troughing can occur before the capillary force can be overcome and this troughing will prohibit a uniform gap from being maintained.

The present invention has now been described with reference to several embodiments thereof. The entire disclosure of any patent or patent application identified herein is hereby incorporated by reference. The foregoing detailed description and examples have been given for clarity of understanding only. No unnecessary limitations are to be understood therefrom. It will be apparent to those skilled in the art that many changes can be made in the embodiments described without departing from the scope of the invention. Thus, the scope of the present invention

should not be limited to the structures described herein, but only by the structures described by the language of the claims and the equivalents of those structures.